ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

LOCALIZATION OF MOBILE TERMINAL IN EMERGENCY SITUATIONS

M.Sc. THESIS

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Department of Electronics and Communication Engineering

Telecommunication Engineering Programme

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To my family,

FOREWORD

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TABLE OF CONTENTS

Page

FOREWORD .... **ix**
TABLE OF CONTENTS .... **xi**
ABBREVIATIONS .... **xiii**
LIST OF TABLES .... **xv**
LIST OF FIGURES .... **xvii**
SUMMARY .... **xix**
ÖZET .... **xxi**
1. INTRODUCTION **25**
2. BACKGROUND **27**
2.1 Fundamental Components 27
2.1.1 Frequency 27
2.1.2 Propagation Model 28
2.1.2.1 Okumura model 29
2.1.2.2 Hata model 31
2.1.2.3 COST-231 model 34
2.1.3 Antenna Characteristics 35
2.1.4 Geographic data 37
2.2 Localization Techniques 38
3. SYSTEM THEORY **41**
3.1 Purpose 41
3.2 Usable Frequency 41
3.3 Propagation Model 41
3.4 Geographic Data 43
3.5 Other Features 44
4. APPLICATIONS AND RESULTS **45**
4.1 Lycian Way Case 45
4.2 Bozdag Mountain Case 47
5. CONCLUSION AND FUTURE WORK **49**
REFERENCES **51**
CURRICULUM VITAE **55**

ABBREVIATIONS

GPS : Global Positioning System
LOS : Line-of-Sight
GLONASS : Global Navigation Satellite System
WLAN : Wireless Local Area Network
LTE : Long Term Evolution
UMTS : Universal Mobile Telecommunications System
GSM : Global System for Mobile Communications
MHz : Megahertz
Hz : Hertz
EURO-COST: European Cooperative for Scientific and Technical
3G : Third Generation
2G : Second Generation
RFID : Radio-Frequency IDentification
AIS : Automatic Identification System
TOA : Time of Arrival
TDOA : Time Difference of Arrival
LMU : Location Measurement Unit
AOA : Angle of Arrival
dB : Desibel
IRAT : Inter- Radio Access Technology
TA : Timing Advance
AFAD : Disaster and Emergency Management Presidency
SIM : Subscriber Identification Module

LIST OF TABLES

Page

Table 3.1 : Clutter class types with losses on 2G and 3G. 43

LIST OF FIGURES

Page

Figure 2.1 : $A_{mu}(f, d)$ over a quasi-smooth terrain [12]. 30
Figure 2.2 : Propagation Loss with the Frequency Changes [12]. 33
Figure 2.3 : Propagation Loss with the Transmitter Height Changes [12]. 33
Figure 2.4 : Comparison of Hata and COST-231 Model. 35
Figure 2.5 : Directional antenna patern[16]. 36
Figure 2.6 : Omni-directional antenna patern[17]. 36
Figure 2.7 : Height Profile and Clutter Maps [21]. 37
Figure 2.8 : 2D positioning with lateration [5]. 39
Figure 3.1 : The calibration process on Atoll [21]. 42
Figure 3.2 : The signalling information for a spesific number 44
Figure 4.1 : The automated area with only one serving base station. 46
Figure 4.2 : The handover related covered area of the 2G and 3G. 46
Figure 4.3 : The intersection of the 2G and 3G coverage areas. 46

LOCALIZATION OF MOBILE TERMINALS IN EMERGENCY SITUATIONS

SUMMARY

When there is an emergency call, the emergency localization system finds the possible location of the mobile phone user. Existing emergency localization systems are only usable when there is more than one serving base station. This kind of system uses triangulation technique with those serving sites. When the coverage is limited with one station, the existing emergency system gives a huge area that is not enough to determine the exact location. The rescue operations of one English and two Danish tourists got lost on the Lycian road in Turkey on 16 Jan 2015. After the tourists got lost, the battery level of their mobile devices became low and rescue with many calls or using GPS was not an option anymore and even if they had enough battery life the signal strength was too weak. The first searching trials with the existing localization system were not very efficient and gave a large area to explore on the trekking road. The reason for this was that it does not working efficiently with only one base station. This system works more efficiently in the case that there was more than one base station. Contrary to the current system, our new developed system works well even with a single base station. The results using the same data were quite different in comparison to the current system's; the area was reduced up to 70%. This also enabled the rescue team to find the lost tourists sooner and easier with the defined location. A similar incident from 8 Feb 2015 is given as a second example. A couple of mountaineers were lost in the Bozdag Mountains in Turkey. Conditions of the terrain and weather were not suitable to locate them with the current systems. The location of the mountaineers was determined using our method. It uses a propagation model and environmental data (e.g. landscape, antenna type, population distributed clutter maps, path loss etc.) and additionally signaling. Moreover, mobile operators have the ability to access information related to signaling between mobile phone and base stations. In this work, we combined those environmental and user data to reduce the area to be searched in order to find the victim's location easier. What makes this approach more important is that it works efficiently even with weak signal and limited battery of the mobile device in emergencies. For similar cases in the future, this system can be automated as a further improvement to the solution.

ACİL DURUMLARDA MOBİL TERMİNALLERİN KONUMLANDIRILMASI

ÖZET

İnsanlar kayboldukları zaman yollarını bulmak ve belirli bir rotada gidebilmek için değişik yöntemleri kullanırlar. Eski zamanlardan beri varolan araştırma merakı sayesinde insanlar uzaklara gitmiş ve gittiği yerleri keşfetmek ve geri dönüş yolunu bulmak için değişik yöntemler kullanmıştır. İlk zamanlarda gökyüzündeki yıldızları, çevredeki ağaçları, taşları gibi yer ve yönlerini bulmak için kullanılırken, sonradan gelişen teknolojiyle birlikte çeşitli yöntemler ve sistemler geliştirilmiştir. Bu yeni sistemler cisimlerin, binaların, cihazların veya insanların konumunun bulunmasında kulanılabilmektedir. Bu sistemler bina içi ve bina dışı olarak ikiye ayrılır. Çeşit ve amacına göre radyo dalagaları, kızılötesi ışınlar, sesötesi dalgalar, manyetik alanlar veya ses sinyallerini kullanabilirler.

Bina dışında konum belirleyen sistemler, arananın bulunduğu alanın nasıl bir ortam olduğuna göre farklı çalışır. Yüksek binaların olduğu ortamda konum belirlemekle, ormanda konum belirleme ya da köy gibi seyrek yerleşim olan yerlerde konum belirleme kullanılan sistemlerin yöntem ve tekniği farklı olur. Bir diğer konu da veri toplayacak sistemlerin sayısı ve çalışma şelidir. Bina içindeki sistemlerde aranan cismi bulmak zordur, bu nedenle alanın genişliğine göre çok sayıda veri alıcı gerekir. Dışarıda kullanılan en yaygın sistem olan GPS'te konumunu arayan cihazın üç tane uydu ile arasında engel olmadan haberleşiyor olması yeterlidir. Engelsiz haberleşirken GPS iyi bir sistemken, kalabalık bir alanda uydu haberleşmesinin zayıf olduğu yerde GPS yetersiz kalacaktır. Her yöntemin avantajları ve dezavantajları olduğu için farklı durumlar için doğru sistemin seçilmesi gerekir.

Mevcut konum belirleme sistemleri temel olarak 3 tekniğe dayanmaktadır. Bunlar literatürde "triangulation", "scene analysis" ve "proximity" olarak geçmektedir. Bu teknikler kullanılan sistemlerde tek başına ya da bir arada olabilmektedir. "Scene analysis" tekniği ile önceki durum karşılaştırması ile yeni objeler ve ortamdaki değişiklikler bulunabilir ya da aynı zamanda farklı noktalardan toplanan bilgi ile gözlemci ile ilgili bilgilere ulaşılabilmektedir. "Proximity" tekniği ise yakındaki cisimleri bulmayı sağlar. Bizim de kullandığımız sistemde olduğu gibi mevcut pek çok sistem ise "triangulation" kullanmaktadır. Bu teknik iki ya da üç ayrı noktanın aranan cismin olabileceği yere uzaklığından ya da yönünden faydalanma esasına dayanır. "Triangulation" tekniği başlıca iki kategoriye ayrılır: "lateration" ve "angulation". İlki mesafe ile ilişkili olup varış süresi (TOA), varış süresi farkı (TDOA) ve sinyal gücü ile ilgilidir. İkincisi ise geliş açısı (AOA), alıcı antenin genlik veya faz tepkisine bağlıdır.

Acil durum araması yapan cep telefonu kullanıcılarının konumları, arama başlattığında yaklaşık olarak mevcut acil durum konum belirleme sistemleri tarafından bulunabilmektedir. Bu tipteki sistemler, servis veren baz istasyonlarından elde ettikleri bilgileri "triangulation" tekniği kullanarak konum bulmaya çalışır. Bu sebeple mevcut sistemler ancak kullanıcının telefonu birden fazla baz istasyonundan servis alıyor ise kullanılabilir. Cep telefonunun bulunduğu yerdeki baz istasyonu kapsaması sadece bir istasyondan sağlanıyorsa mevcut acil sistemler konumun yeterli kesinlikte belirlenebilmesine yeterli olamayacak kadar büyük bir alanı ancak verebilmektedir.

Bu tip sistemlerde kullanılan frekans bandı da değişmektedir. Bizim yöntemimizde ikinci nesil teknoloji sinyalleri kullanılırken 900 MHz, üçüncü nesil teknoloji sinyalleri kullanılırken ise 2100 MHz bandı kullanılmıştır.

Diğer bir önemli konu da propagasyon modelidir. Bizim sistemimiz için propagasyon modeli oluşturmak için kapsama tahmin programındaki standart modeller kalibre edilmiş, böylece kendi modelimizdeki "pathloss" formülündeki değişkenler hesaplanmıştır. Bu değişkenler hesaplanırken seçilen pilot sahalara omni antenler konmuş ve saha çevrelerinde ölçüm alınmıştır. Sonra ölçüm sonucundaki gerçek değer ile hazır modelden evrilen model hazırlanmış ve iyileştirilmiştir. Bu şekilde hem 2G hem de 3G için iki ayrı model oluşturulmuştur.

Kapsama bazlı konum bulunurken bir diğer önemli unsur da coğrafi data ve dağılımlarıdır. Çünkü bir baz istasyonunun kapsama alanını bulabilemk için frekans ve propagasyon modelin yanında yer yüzeyi şekilleri ve coğrafi olarak oralarda ne tip bir yapının olduğu da çok önemlidir. Buna örnek olarak gökdelenlerin olduğu yer ile göl çevresindeki bir yerleşimde baz istasonunun kapsama alanının çok farklı bir sonuç vereceği söylenebilir.

Bir diğer önemli unsur ise tek baz istasyonu olma durumunda kullandığımız handover denen baz istasyonunun hücreleri arasındaki geçişlerdir.

Bir İngiliz ve iki Danimarkalı turistin 16 Ocak 2015 tarihinde Likya yolunda kaybolması sebebiyle bir kurtarma operasyonu başlatıldı. Turistler kaybolduğu zaman cep telefonlarının pil seviyesi çok azdı ve telefon ile görüşerek konumları hakkında yeterli bilgi vermeye veya GPS kullanmalarına imkan vermeyecek durumdaydı. Yeterli pil seviyeleri olsaydı bile sinyal gücü çok zayıf olduğu için bu yöntemler sonuç vermeyecekti. Mevcut konum belirleme sistemi ile başlatılan ilk arama çalışmaları çok etkili değildi çünkü sistem yürüyüş yolunun olduğu bölgede mahsur kalan kişilerin olabileceği bölge için çok büyük bir alanı belirleyebilmişti. Bunun nedeni turistlerin telefonunun sadece bir baz istasyonundan servis alıyor olmasıydı. Telefonun servis aldığı baz istasyonu sayısı birden fazla olsaydı kullanılan triangulation tekniği sayesinde turistlerin mahsur kaldığı tahmini alan daha da küçültülebilirdi. Şu an kullanılan sistemin aksine bizim geliştirdiğimiz sistem tek bir baz istasyonu ile bile etkili sonuçlar verebilmektedir. Aynı veriler kullanılarak elde edilen sonuçlarda gözle görünür bir fark ortaya çıktı; turistlerin bulunduğu tahmini alan mevcut sistemin belirlediğinden %70 oranında küçülterek belirlendi. Böylece kaybolan turistlerin yeni belirlenen bölgede çok daha erken ve kolay bulunması sağlandı.

8 Şubat 2015 tarihinde yaşanan bir başka olay da bize bir diğer örnek sunabilir. Bir çift dağcı Türkiye sınırları içerisindeki Bozdağlar'da mahsur kaldı. Bölgenin yapısı ve hava koşulları nedeniyle mevcut sistemle kayıp dağcıların kaldığı yerin belirlenmesi pek mümkün değildi. Fakat bizim yöntemle mahsur kalan dağcıların konumlarının belirlenmesi mümkün oldu. Yöntem genel olarak bir propagasyon modelini, çevresel verileri (coğrafi şekiller, anten tipi, nüfuz dağılımını gösteren haritalar, sinyalin kullanıcı telefonuna ulaşana kadar yolda verdiği güç kaybı vs.) ve ek olarak sinyalleşmeyi kullanarak sonuca ulaşır. Bunlara ilave olarak Mobil İletişim operatörlerinin baz istasyonu ile mobil telefonlar arası sinyalleşme bilgilerine de erişme imkanları vardır. Bu çalışmada mahsur kalan kişilerin konumlarının daha kolay bulunabilmesi amacıyla arama yapılacak alanı daraltmak için biz bu çevresel verileri ve kullanıcıdan elde ettiğimiz bilgileri birleştirerek sonuca ulaştık.

Bizim yaklaşımımızı önemli kılan ise acil durumlarda zayıf sinyal ve düşük pil seviyesinde, mevcut sistemlerin çalışmadığı durumda, etkili şekilde çalışmasıdır. Bu yaklaşımın bir ileri adımı ise sistemi otomatikleştirerek gelecekte yaşanabilecek benzer durumlar için daha erken ve daha hızlı müdahele imkanının sağlanması ile daha çok insanın kurtarılabilmesi olacaktır.

1. INTRODUCTION

People are using different techniques to find ways and track routes. From ancient times they started to explore and use natural ways like putting stones, marking trees and using stars in the sky to avoid losing the way. Another issue is how to find people who are lost. Thus, location finding becomes important and different location finding methods are used such as searching groups, signal cartridge, radar, GPS etc.

With improving technology and increasing mobility, new localization systems are being developed. These systems are for positioning or determining the location of the mobile devices, objects, buildings or people. These can be separated into indoor (inside the building) and outdoor (outside of the building in different areas like rural, urban etc.) systems. These systems use radio waves, infrared waves, ultrasound waves, magnetic fields or sound signals.

When there is a clear path, which is without obstructed objects, between the transmitter and the receiver, it is called line of sight (LOS). Localization systems like GPS, GLONASS and Galileo are effective especially for outdoors. GPS requires LOS to the satellites which makes it difficult to locate devices indoors. GPS needs three satellites to find location as latitude and longitude and four satellites to include the altitude value of the location [1]. That is why GPS is not enough to determine the location inside buildings. The indoor locating systems, which are good for indoor positioning, are required when the mobile device is inside a building. Wireless radio signal based RADAR system gathers data, uses the signal strength and combines it with a model to find the location of the users inside the building especially for location based services [2]. The novel technique with 92% accuracy level for 2 meters, which was tried at a museum of about 800m^2 areas with only nine access points, uses WLAN 802.11b signals for indoor localization [3]. Cricket, which has an algorithm that increases efficiency on beacons, is used for indoor localization with the low cost cricket devices [4].

Today, there are dozens of different systems used to determine the location of the object. All can be grouped under three main techniques; which are triangulation, scene analysis and proximity [5]. Some technologies use only one of the techniques; some of them use a combination of them. Most of the localization systems are using triangulation technique. The process of determining the location of the transmitter from two or three distinct points with measure of the radial distance or the direction is triangulation [6].

The existing emergency system, which uses triangulation technique, requires more than one serving base station and more base stations means more accurate location estimation. When there is only one serving base station this technique is not sufficient to determine the mobile device's location. Therefore, new algorithms are needed to solve this kind of situation. The estimated location area can be given with our method. Our system is based on the coverage of the radio frequency signals and handover algorithms. The successful results can be achieved even with our system when the signal level and the battery of the device is low.

The remaining paper is organized as follows.

In section 2, the background of the work is explained; the fundamental components of our system and the localization techniques are given in general.

Section 3 presents the theory of the proposed system with the sample data.

Section 4 highlights the applications and the results of the algorithm.

Finally, Section 5 gives the conclusions of my paper. It also gives the uses and the benefits of my system.

2. BACKGROUND

Currently, there are many alternative localization systems in use. For different cases, different methods will be chosen to locate the objects depending on the methodology and constraints of the case. The existing systems might be not sufficient in some of the situations (e.g. indoor, outdoor, the number of data sources, battery of the devices etc.). The biggest advantage of our solution is that it can find the probable location area of the object when the signal level and the mobile phone battery are low. To find it, we will use firstly the coverage of the serving antenna. Then if the handover information exists, it will be used to reduce the area of the coverage.

2.1 Fundamental Components

In our localization system there are important parameters which effect whole process. The fundamental objects of our system are frequency, propagation model, path loss, antenna characteristics and geographic data.

2.1.1 Frequency

Frequency has an important effect on the coverage; higher frequencies carry signal for lesser distances, though lower frequencies can go far. Our system uses the serving site's coverage to find the location. Coverage depends on the frequency and changes inversely proportional. A lower carrier frequency will propagate further than the higher one on the same technology. Like with LTE technology, 800 MHz is mostly used for coverage, and 2600 MHz frequency is generally used for capacity. The usage of 800 MHz with 10 MHz bandwidth reduced the required site number by 80% in Sweden for rural areas [7]. Moreover, the technology that uses the same frequency affects the distances differently. As Fischer et al said, the 900 MHz frequency with

UMTS technology has approximately 3 dB advantage compared to GSM 900, thus it goes further away than the 900 MHz on GSM [8].

2.1.2 Propagation Model

One of the required parameters to calculate the coverage is the path loss. While radio waves propagate through space, they are exposed to attenuation, this reduction is path loss. There are different parameters that should be known to calculate the path loss. The parameters like gain of the antenna, the height and the location of the antenna, cable losses, weather conditions, free-space loss, refraction, diffraction, reflection and aperture-medium coupling loss, absorption affect the path loss value.

The path loss in free space for an isotropic point source is the free space path loss. It can be calculated as in the equation (2.1) in terms of dB [9].

$$L_0 = 20\log(\mathrm{d}) + 20\log(\mathrm{f}) + 20\log\left(\frac{4\pi}{c}\right) \qquad (2.1)$$

Where:

d: Distance between transmitter and receiver (m)

f: Carrier frequency [Hz]

c: Speed of light (m/s)

The free space path loss cannot be used in general on the realistic propagation models; path loss should change with the model. In the real world, radio waves propagate through the space, which is not a free one. The waves usually encounter an obstacle and change the attribute as reflection, diffraction and scattering, which are the three main mechanism of propagation [10]. If there is no LOS between the receiver and the transmitter, radio waves have different attitude known as multipath propagation. While propagating the radio waves hit big objects, such as earth or building, thus reflection occurs. The reflection is appeared when the dimension of the object is much larger than the electromagnetic wavelength [11]. The obstacle may not have a flat surface and may have flaws, so the waves bend and this is called diffraction, it explains how radio signals can travel without LOS. The last one is scattering, it happens when waves encounter small obstacles like the pond, bushes, street signs and lamps, or rough surfaces. The scattering happens when the wavelength is larger than the medium where the electromagnetic waves propagate through [10].

Path loss is investigated in two ways, related with the distance or the passing time between the transmitter and the receiver. When the radio waves encounter with an obstacle at very long distances or there is line of sight between transmitter and receiver this is named as large scale path loss. If the distance is small or there are many obstacles that change the direction of the signal rapidly, this is called small scale path loss. The method to be used will be chosen based on the type of the pathloss.

The propagation models are the most important factor to calculate the coverage distances. Every propagation model has its own path loss value. The different models are improved based on the signal measurements in different places and different situations. The models can be designed for different environments like urban, rural, dense urban, suburban, desert, forest or sea etc. The models are also related with the distance and the frequency. The weather and atmospheric conditions also effect the propagation.

2.1.2.1 Okumura model

The most popular propagation model is Okumura Model, which is the standard model for Japan, and is widely used in urban areas where the building heights are not so high [11]. The model is for 150 Mhz to 1920 Mhz (it is also extended to 3000 Mhz) frequency range, 1km to 100 km distances, base station effective heights should be greater than 30 meters and mobile antennas effective heights should be less than 10 meters. Okumura models for suburban and open areas were developed later. Open areas are without buildings and tall trees in path. Suburban is the area with small, one or two floor houses not close to each other like in the villages[12]. The propagation models are represented with the calculation of the path loss value of the model. Okumura model is formulated as in equation (2.2).

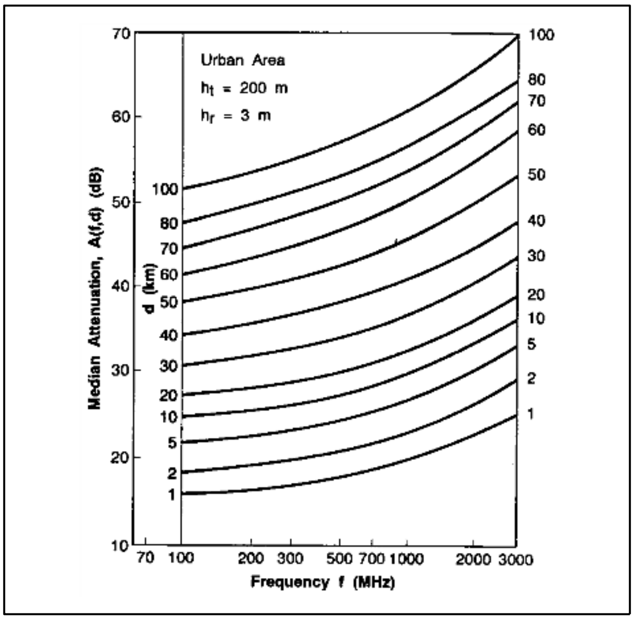


Figure 2.1 : $A_{mu}(f, d)$ over a quasi-smooth terrain [12].

$$L_p(dB) = L_F + A_{mu}(f,d) - G(h_t) - G(h_r) - G_{AREA} \tag{2.2}$$

Where;

L_p : Median value of propagation path loss

L_F : Free space propagation loss.

A_{mu}(f,d): Median attenuation in the medium relative to free space.

f: Radio frequency

d: Distance between the base and the mobile unit

$G(h_t), G(h_r)$: Gain factor for base station and mobile antenna height

h_t: Effective height of the base station

h_r : Effective height of the mobile antennas

G_{AREA}: Gain related with the type of given environment

The variation of attenuation depending on the frequency change between 100 MHz and 3000 MHz is shown on Figure 2.1. As it can be seen on the figure, the attenuation and frequency are related.

Base station and mobile antenna gain are related to the effective height values. The gains can be calculated as in equation (2.3), (2.4), (2.5)[10].

$$G(h_t) = 20\log(\frac{h_t}{200}) \qquad \text{where } 1000 \text{ m} > h_t > 30 \text{ m} \qquad (2.3)$$

$$G(h_r) = 10\log(\frac{h_r}{3}) \qquad \text{where } h_m \leq 3\ m \qquad (2.4)$$

$$G(h_r) = 20\log(\frac{h_r}{3}) \qquad \text{where } 10 \text{ m} > h_m > 3 \text{ m} \qquad (2.5)$$

The main disadvantage of Okumura model is the slow response to the fast terrain profile change.

2.1.2.2 Hata model

Hata, M. developed an empirical formula for propagation loss to use the Okumura's prediction methods in computations [14]. There are different versions for urban, suburban and rural areas for the Hata model. It is used between 150-1500 MHz and is a good model to use for GSM 900 technology. Because the frequency range is not in the range of UMTS 2100, that model cannot be used with UMTS 2100. The supported range starts from 1km and is restricted to 20 km, base station effective heights like Okumura's are greater than 30 m and restricted to 200 m. Mobile antenna effective height range is a bit different, it should be between 1- 10 meters. According to these values, Hata model is generally formulated as in equation (2.6).

$$L_p(dB) = [69.55 + 26.16\ logf - 13.82logh_t - a(h_r)] + (44.9 - 6.55\ logh_t)\log R \qquad (2.6)$$

Where;

Lp : Median value of propagation path loss

f: Radio frequency

h_t : Effective height of the base station

h_r : Effective height of the mobile antennas

$a(h_r)$: Correction factor of the effective height for the mobile antenna

R: Distance

Correction factor $a(h_r)$ is given as equation (2.7) for small-to-medium sized cities and for large cities as equation (2.8) and (2.9)

$$a(h_r) = (1.1logf - 0.7)h_r - (1.56logf - 0.8) \tag{2.7}$$

$$a(h_r) = 8.29(log1.54h_r)^2 - 1.1 \qquad \text{where} \quad f \leq 300 \text{ MHz} \tag{2.8}$$

$$a(h_r) = 3.2(log11.75h_r)^2 - 4.97 \qquad \text{where} \quad f \geq 300 \text{ MHz} \tag{2.9}$$

Propagation loss is calculated with Hata model in urban area with the transmitter height at 70 m and the receiver at the 1.5 m from the ground. First calculations are at four different frequencies between 150 MHz to 1500 MHz. As it can be seen on Figure 2.2, propagation loss increases with the frequency.

On the Figure 2.3, frequency is fixed to 900 MHz and the transmitter height is changed between 30 m and 200 m. The result is like in the Figure 2.3, loss decreases with the higher transmitter heights.

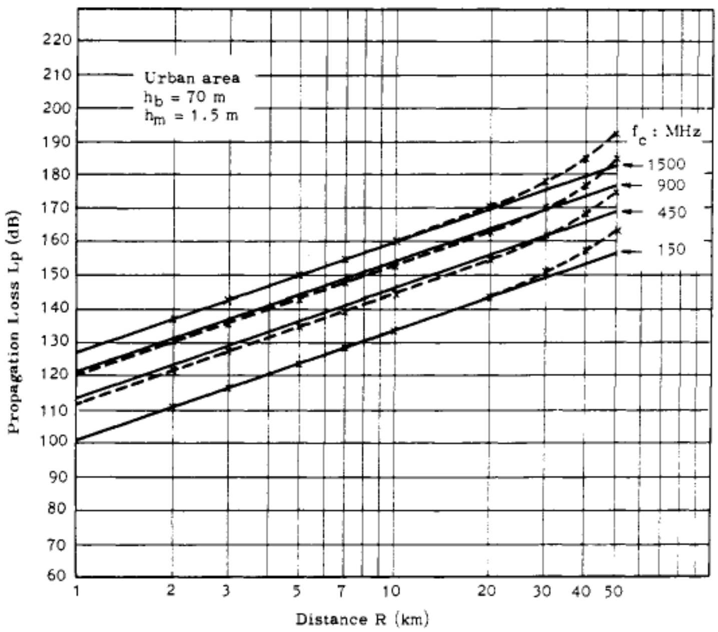


Figure 2.2 : Propagation Loss with the Frequency Changes [12].

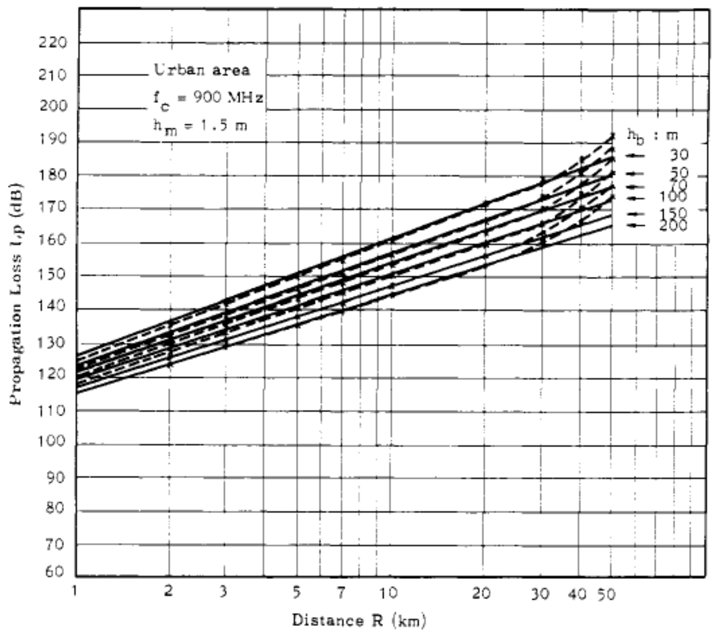


Figure 2.3 : Propagation Loss with the Transmitter Height Changes [12].

The general Hata path loss formula in (2.6) is for urban areas. The equation is modified for suburban areas as in the equation (2.10) and for the open rural areas as in the equation (2.11) as bellow:

$$L_{ps} = L_p(urban) - 2[\log(\frac{f}{28})]^2 - 5.4 \tag{2.10}$$
$$L_{po} = L_p(urban) - 4.78(logf)^2 - 18.33logf - 40.98 \tag{2.11}$$

Hata model is suitable for large cell mobile systems, because the range starts from one km which means this model is not for the personal communication systems with small range.

2.1.2.3 COST-231 model

Cost-Hata is developed from urban Hata Model. The path loss of the model can be calculated as combination of three different losses like in the equation (2.12)[15]. L_0, L_{rts}, L_{msd} are “Free-Space loss”, “Roof-Top-to-Street diffraction and scattering loss” and “Multi-Screen Diffraction loss”.

Extended version of the Cost-Hata model formula was changed and named as COST-231 by the European Cooperative for Scientific and Technical research (EURO-COST)[10].The parameters are restricted like below ranges:

f: Radio frequency is between 1500-2000MHz.

h_t : Effective height of the base station 30-200 m

h_r : Effective height of the mobile antennas 1-10 m

R: Distance 1-20 km

In the same components of frequency, technology (3G 2100 MHz), signal level(-107 dBm), antenna characteristics and geographic data (mostly villages and forest), if only the propagation model changes the coverage change is like in the Figure 2.4. Okumura model does not work properly because the model is designed for urban clutters.

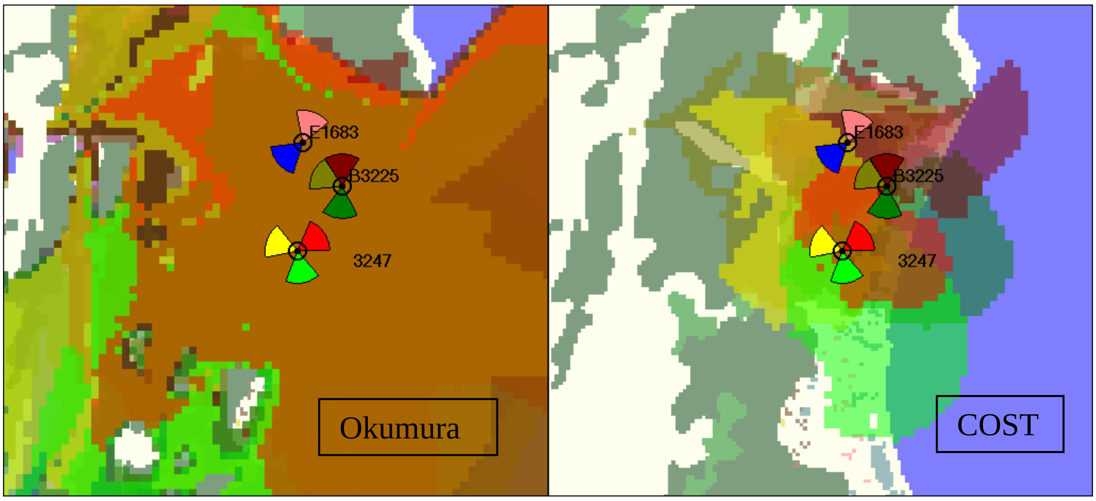


Figure 2.4 : Comparison of Hata and COST-231 Model.

2.1.3 Antenna Characteristics

Another required parameter to affect the coverage is antenna characteristics. Antenna gain, horizontal and vertical pattern are changed with the antenna model. Antenna radiation can be omni-directional or directional (figure 2.5, 2.6). In mobile communication, the basic planning rule-sectoring- supports the directional antennas, by this way narrow and crowded areas are covered well. The purpose on mobile planning is to achieve the desired coverage, this is provided simplest with the directional antennas.The omnidirectional antennas oppositly are for the open areas, or they can be used for the model modifications to collect the signal data. The horizontal pattern shows the radiation according to azimuth, so it is affected by antenna height. The vertical pattern shows the radiation for elevation; therefore, it is related with the electrical and the mechanical tilt of the antenna.

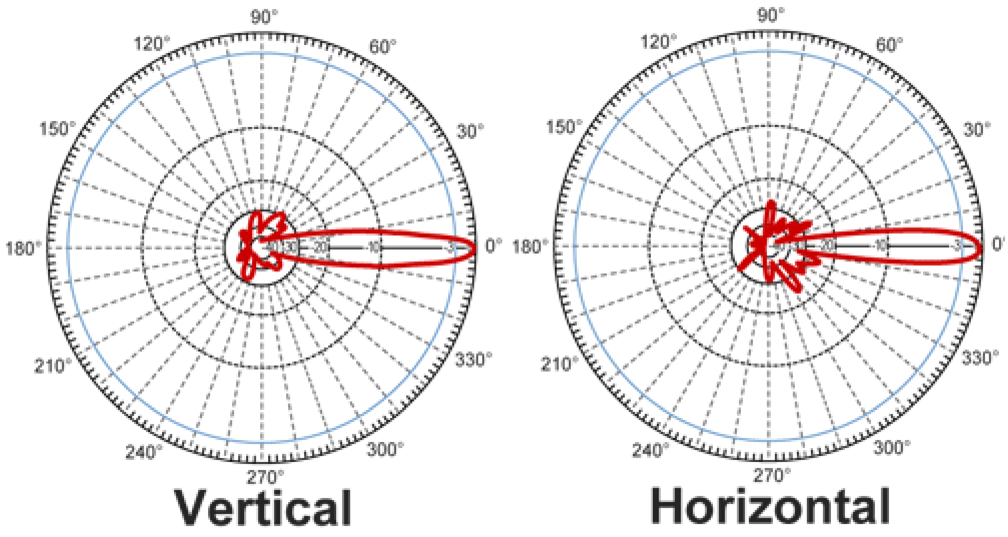


Figure 2.5 : Directional antenna patern[16].

Moreover, to calculate the coverage, the antenna’s side lobes and back lobes are the most important factors. All of these characteristics should be considered to prepare a model right.

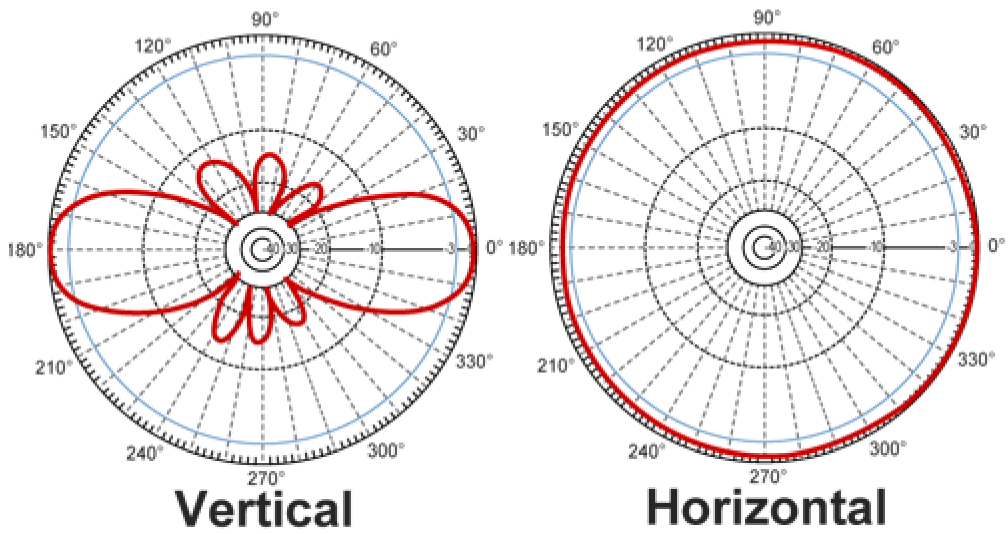


Figure 2.6 : Omni-directional antenna patern[17].

2.1.4 Geographic data

Geographic data is another crucial factor for the coverage calculations. The digital terrain model, clutter classes, clutter heights are the important geographic data examples. The digital terrain model is the elevation of the ground over sea level. Clutter classes are type of the ground like; forest, building, sea, industrial area, village, open areas etc. and every class of the clutter has its own loss value. The example of the terrain model with clutter classes can be seen on Figure 2.7. The related signal distribution is calcuted considering that the profile and the clutter classes and using it the coverage can be achieved.

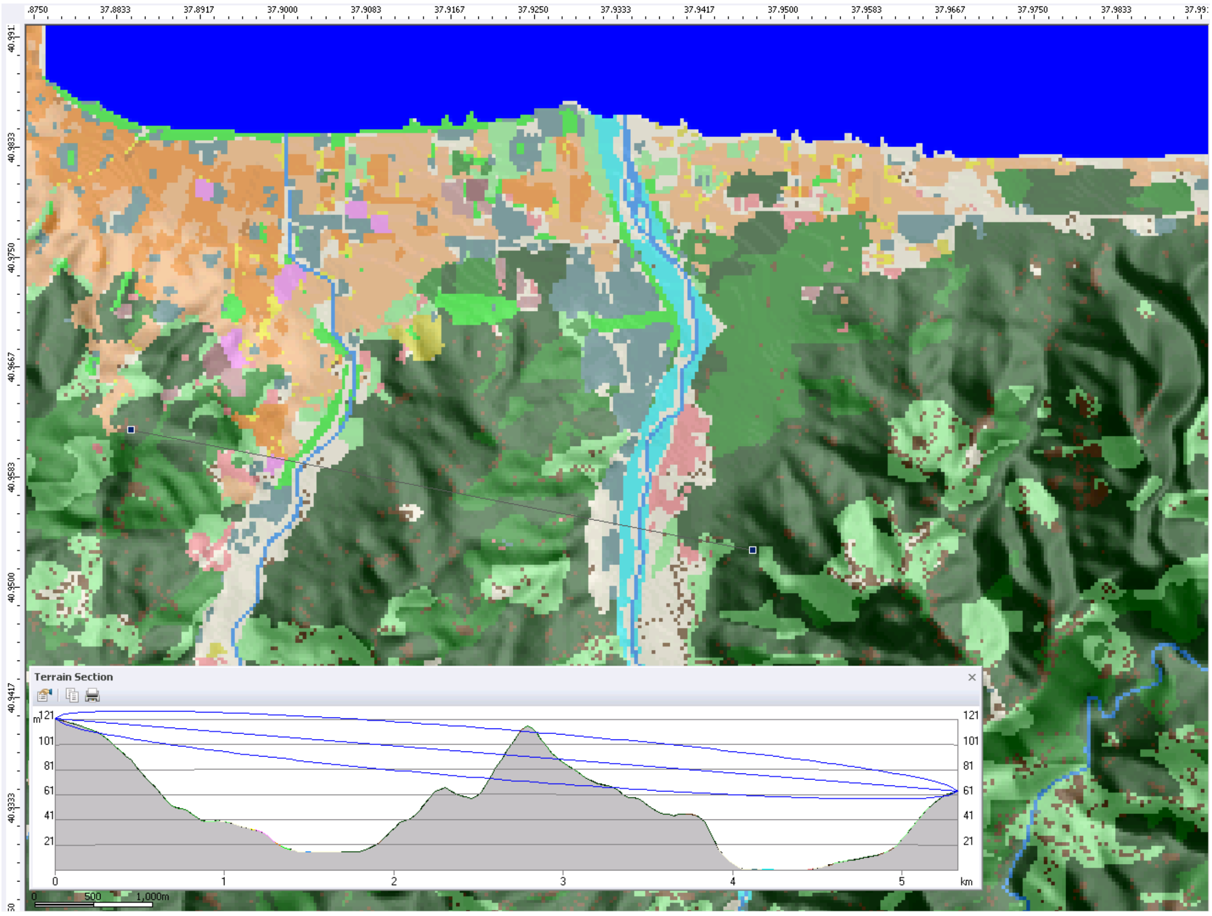


Figure 2.7 : Height Profile and Clutter Maps [21].

2.2 Localization Techniques

There are three main techniques for localization: Triangulation, Scene analysis and Proximity.

Proximity technique is used to detect nearby objects. RFID systems, car parking sensors, some touchscreen devices, Active Badges, Cricket and AIS(Automatic Identification System) on ships can be given as examples for application of this technique.

Scene Analysis technique compares the existing and the previous scene to identify the new objects and multiple scenes at the same time from different points to find the observers. For example, Microsoft's RADAR system matches the signals received from indoor WiFi Access Points to find the objects [18].

Triangulation techniques can be differentiated in two main categories, lateration and angulation [5]. Lateration is related with the distance and angulation is related with the angle of arrival. Time of Arrival (TOA), Time Difference of Arrival (TDOA) and signal strength are all related with lateration technique. TDOA based different techniques are used on the Location Measurement Unit (LMU) [19]. Angle of Arrival (AOA) is related with angulation. There are two different AOA techniques: one uses the amplitude response and the other uses phase response of the receiver antenna [20].

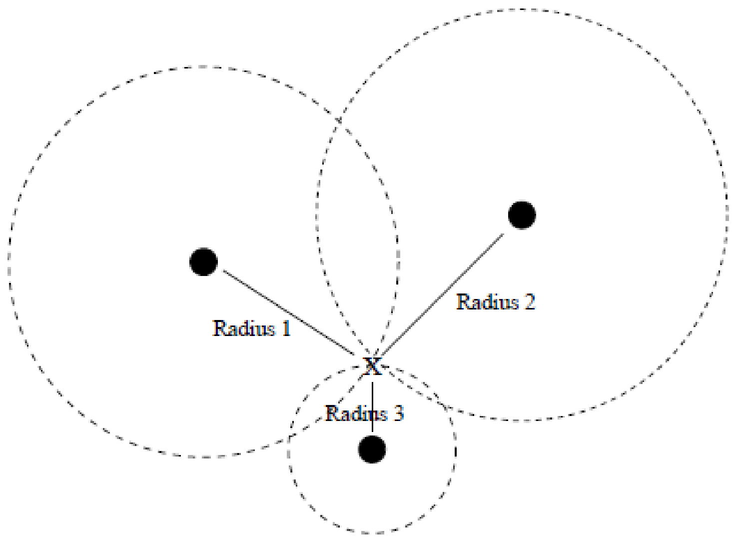


Figure 2.8 : 2D positioning with lateration [5].

As seen on the figure 2.8, the position of the object can be found by measuring its distance from multiple reference points. To find location in two dimensions, the three collinear points are required [5].

Some systems are using triangulation as combination with the other techniques such as RADAR and Cricket. Moreover, Active Badges' improved version Active Bat systems, US emergency system E911 and GPS use triangulation technique. Our system based on AOA and TOA lateration techniques.

3. SYSTEM THEORY

3.1 Purpose

We develop a localization model for low battery and/or low signal strength situation. When the battery level of the mobile device is low, making calls to define the location or using GPS is not an option to find the location. When the existing information is not enough to determine the victims location with the existing systems, many of them can be saved with our method.

3.2 Usable Frequency

Our new localization algorithm is working on 900 MHz 2G and 2100 MHz 3G, which are now usable frequencies for Vodafone Turkey mobile operator. Regarding the frequency characteristics, 2G signals are going much further than 3G signals. This is a benefit for the location finding with 3G technologies, if the 3G coverage exists.

3.3 Propagation Model

We have our general 2G and 3G propagation models. We improved these models from the standart propagation model in Atoll programing tool [21]. We prepare our model based on the measurements at different locations. These measurements are related with the signals that are sent from base stations by omni antennas. To prepare our model the LOS signal information removed from the test data and then these measurements are used to calibrate the Standart Propagation model in Atoll planning tool. This process made for thousands of site at tens of different regions. Firstly, models are prepared for each region, then that information used to prepare a general one. The city based models can have significant difference between each other, because of the geographical properties, residential system and the population distribution. Our localization method is special also with its propagation model. Our model is calibrated with Atoll Planning Tool, where the mathematical coverage data from the general model and the calculated coverage data from the selected field are compared. The propagation model is prepared and this process is called model-tuning (Figure 3.1). Finally two general models for different technologies were prepared as 2G model and 3G model. Those propagation models have the standard deviation of 9 at the urban and 7 at the rural areas.

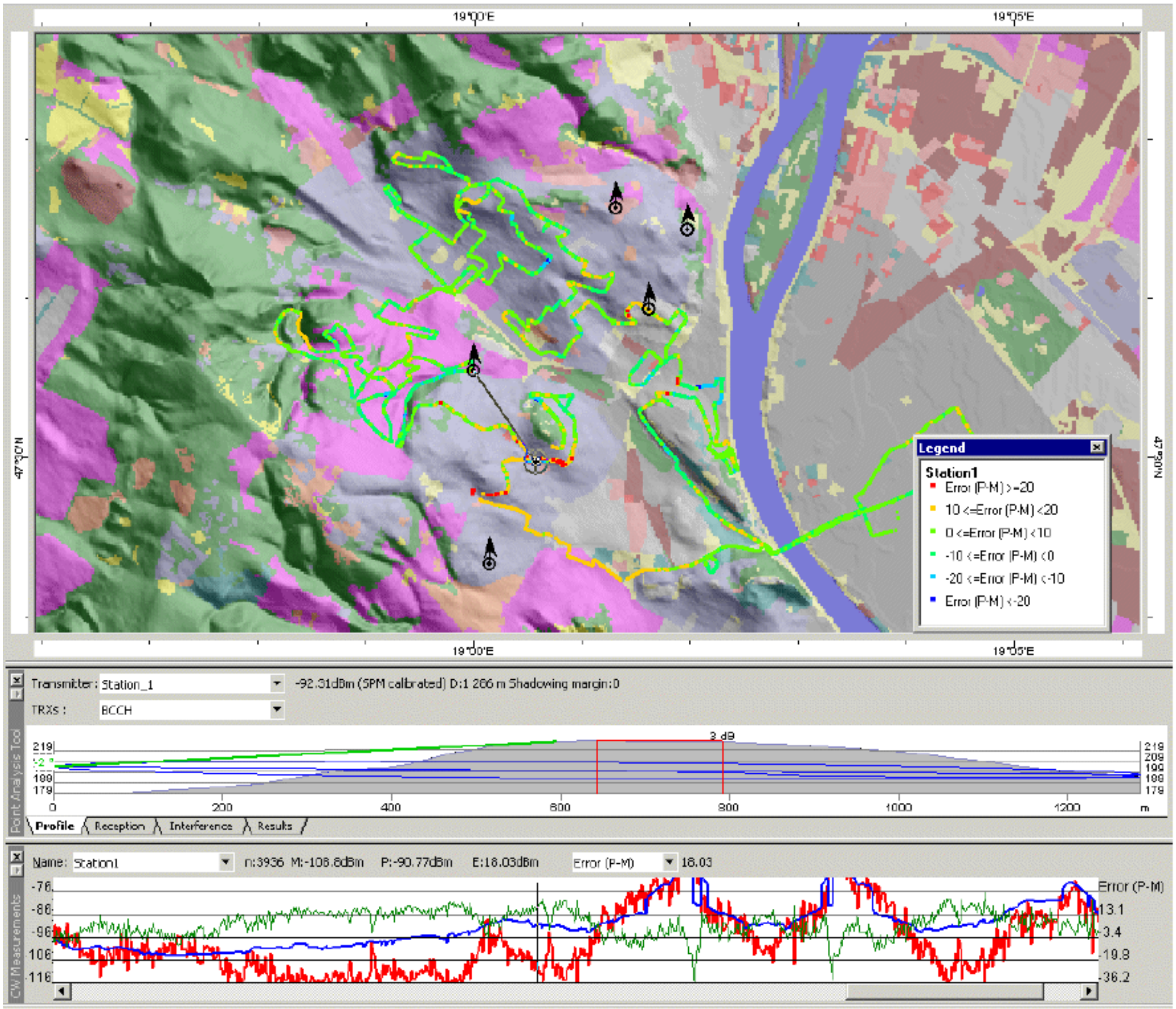


Figure 3.1 : The calibration process on Atoll [21].

The important thing is to keep the maps and base staton information updated and to make the necessary changes on the model if there is a big change in the cities. All base station and cell information are up to date on the databases, which is used directly by Atoll program. Before opening a new base station, the related cell data should be updated on a daily basis. All of these actions increase the accuracy of the coverage simulations.

3.4 Geographic Data

We calculate the coverage and the distances depending 25 clutter class maps, defined in the **Table 3.1** and the terrain model with the selected propagation model on the planning tool.

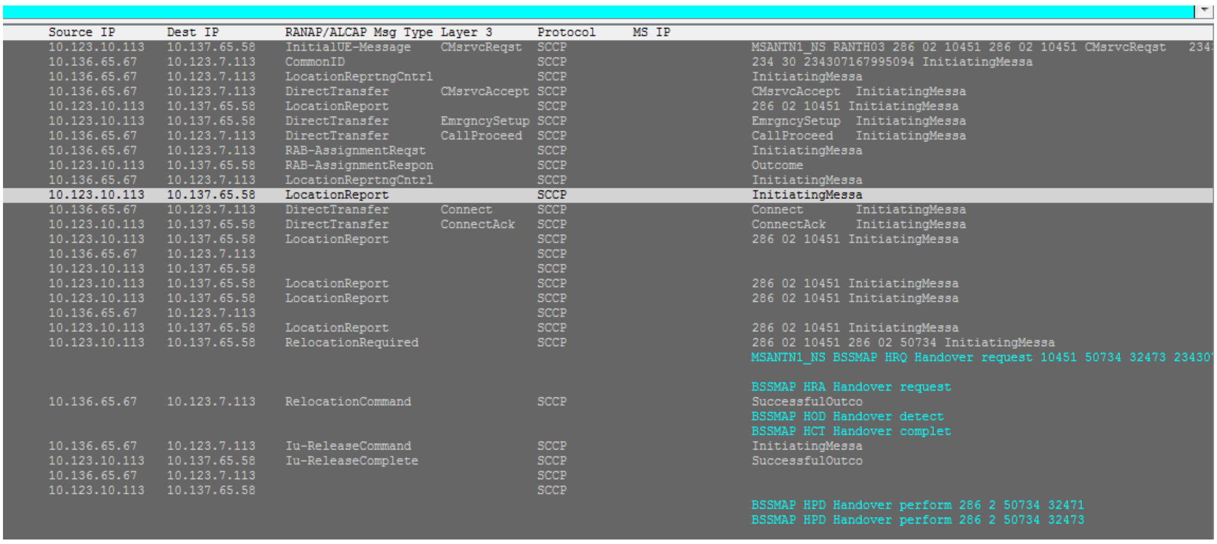
Table 3.1 : Clutter class types with losses on 2G and 3G.

Name	Standard Deviation (dB)	GSM Indoor Loss (dB)	UMTS Indoor Loss (dB)
Buildings	9	21	20
Denseurbanhigh	9	26	24
Denseurban	9	26	24
Denseurbanlow	9	26	24
Taxarea	9	17	13
Denseblockbuildingshigh	9	26	24
Denseblockbuildings	9	26	24
Blockbuildingshigh	9	21	20
Blockbuildings	9	21	20
Meanurban	9	21	20
Highresidential	9	17	13
Lowresidential	9	17	13
Temporary	7	9	9
Villages	7	9	9
Industrial_Commercial	9	21	20
Parks	7	9	9
Semiopenarea	7	0	0
Sparseforest	7	0	0
Forest	7	0	0
Openwetarea	7	0	0
Inlandwater	7	0	0
Sea	7	0	0
Openinurban	7	4	4
Openland	7	0	0
Othercountries	7	0	0

3.5 Other Features

The other features, which can be used for localization, are handover and timing advance information. The transferring an ongoing call or data session between different cells is handover. We use the Intercell, Intracell and IRAT cell handover relations on 2G and 3G. Inter cell handover is between different cells, it can be on the same site or not. Intra cell handover is one the same cell different channels, or between on the same sector, different cells. IRAT cell handover is between the cells on different radio access technologies. Timing advance is 2G based range value, which calculates the distance between base station and the mobile phone based on the length of the time of signal takes in the air. It will change between 0 and 63 number values and every value corresponds 550 meters.

When there is an emergency call, the mobile operators have the right to check the signaling information for the specific mobile phone number. There is much information like the handover and the timing advance on that special program (Figure 3.2).



Source IP	Dest IP	RANAP/ALCAP Msg Type	Layer 3	Protocol	MS IP	
10.123.10.113	10.137.65.58	InitialUE-Message	CMsrvcReqst	SCCP		MSANTN1_NS RANTH03 286 02 10451 286 02 10451 CMsrvcReqst 234
10.136.65.67	10.123.7.113	CommonID		SCCP		234 30 234307167995094 InitiatingMessa
10.136.65.67	10.123.7.113	LocationReprtngCntrl		SCCP		InitiatingMessa
10.136.65.67	10.123.7.113	DirectTransfer	CMsrvcAccept	SCCP		CMsrvcAccept InitiatingMessa
10.123.10.113	10.137.65.58	LocationReport		SCCP		286 02 10451 InitiatingMessa
10.123.10.113	10.137.65.58	DirectTransfer	EmrgncySetup	SCCP		EmrgncySetup InitiatingMessa
10.136.65.67	10.123.7.113	DirectTransfer	CallProceed	SCCP		CallProceed InitiatingMessa
10.136.65.67	10.123.7.113	RAB-AssignmentReqst		SCCP		InitiatingMessa
10.123.10.113	10.137.65.58	RAB-AssignmentRespon		SCCP		Outcome
10.136.65.67	10.123.7.113	LocationReprtngCntrl		SCCP		InitiatingMessa
10.123.10.113	10.137.65.58	LocationReport		SCCP		InitiatingMessa
10.136.65.67	10.123.7.113	DirectTransfer	Connect	SCCP		Connect InitiatingMessa
10.123.10.113	10.137.65.58	DirectTransfer	ConnectAck	SCCP		ConnectAck InitiatingMessa
10.123.10.113	10.137.65.58	LocationReport		SCCP		286 02 10451 InitiatingMessa
10.136.65.67	10.123.7.113			SCCP		
10.123.10.113	10.137.65.58			SCCP		
10.123.10.113	10.137.65.58	LocationReport		SCCP		286 02 10451 InitiatingMessa
10.123.10.113	10.137.65.58	LocationReport		SCCP		286 02 10451 InitiatingMessa
10.136.65.67	10.123.7.113			SCCP		
10.123.10.113	10.137.65.58	LocationReport		SCCP		286 02 10451 InitiatingMessa
10.123.10.113	10.137.65.58	RelocationRequired		SCCP		286 02 10451 286 02 50734 InitiatingMessa
						MSANTN1_NS BSSMAP HRQ Handover request 10451 50734 32473 23430
						BSSMAP HRA Handover request
10.136.65.67	10.123.7.113	RelocationCommand		SCCP		SuccessfulOutco
						BSSMAP HOD Handover detect
						BSSMAP HCT Handover complet
10.136.65.67	10.123.7.113	Iu-ReleaseCommand		SCCP		InitiatingMessa
10.123.10.113	10.137.65.58	Iu-ReleaseComplete		SCCP		SuccessfulOutco
10.136.65.67	10.123.7.113			SCCP		
10.123.10.113	10.137.65.58			SCCP		
						BSSMAP HPD Handover perform 286 2 50734 32471
						BSSMAP HPD Handover perform 286 2 50734 32473

Figure 3.2 : The signalling information for a spesific number

4. APPLICATIONS AND RESULTS

In this paper, our different solution method for the locating the mobile phone is explained. The distinctive thing is the effective results on the low signal strength situations. In addition to the low signal situation, the method is highly effective on the low battery condition.

There are two real situations that it can be seen that our system works successfully. The first one is localization of the students who were got lost on the trekking road, Lycian Way near Antalya. The second one is the missing mountaineers at the Bozdag mountain, near Izmir.

4.1 Lycian Way Case

Three university students (one from England and two from Netherlands) got lost during Lycian Way walk on 16th January, 2015 in Antalya city rural area. Immediately AFAD (Disaster and Emergency Management Presidency) rescue team had requested emergency call logs from all mobile operators to assist the rescue operation. The rescue teams first used the area, which automatically generated like seen on figure 4.1.

The students haven't got a local SIM, so they're on roaming and they can be connected on any mobile operator of Turkey. First 3 days of missing, none of the students made a call on Vodafone network. Unfortunately, the lost students could not be found despite 70 rescue staff searching for three days in a rural area. Then on the third day, luckily one of the students made an emergency call on Vodafone network. We use that signaling information to restrict the area.

On the call information, the signalling handed over between first sector of 3G and third sector of 2G, covered area can be seen in the figure 4.2. We used the intersection of these two different coverage areas and gave the estimated area to the rescue team (Figure 4.3). All analyse, decision and calculation process within 4 hours and 30 minutes. Finally, within the perfect coordination, an innovative approach, and the lost students were found alive in one hour after the rescue team started searching in a defined area.

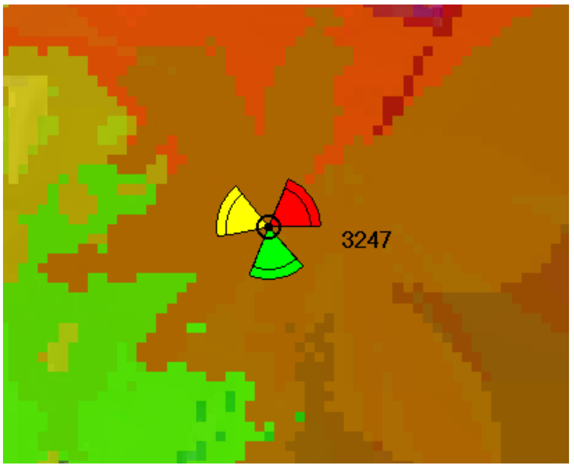


Figure 4.1 : The automated area with only one serving base station.

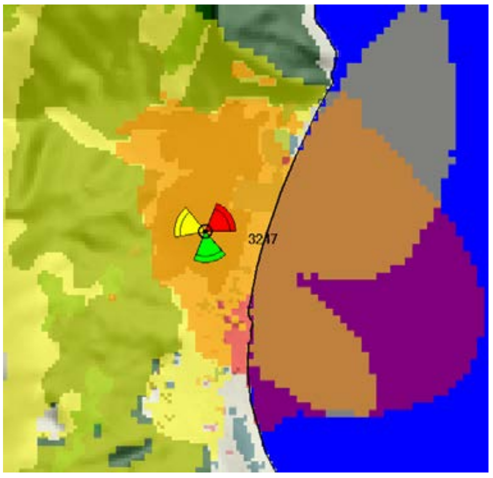


Figure 4.2 : The handover related covered area of the 2G and 3G.

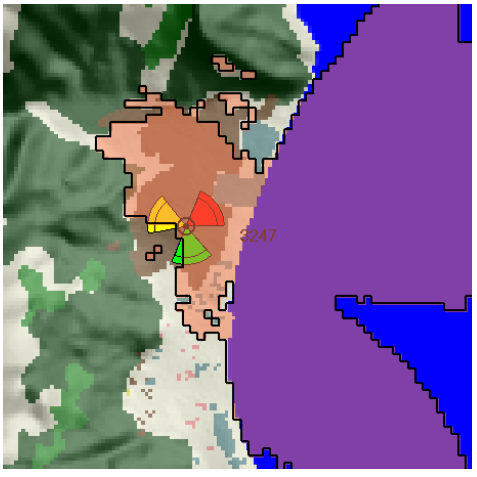


Figure 4.3 : The intersection of the 2G and 3G coverage areas.

4.2 Bozdag Mountain Case

A couple of mountaineers were lost in the Bozdag Mountains in Turkey on 8 Feb 2015. Conditions of the terrain and weather were not suitable to locate them with the current systems. Another method is used to find the location. In this case, our method is based on the TOA and AOA. The serving cell is analyzed for some of the mountainers' mobile phone signaling data. The decision is to use the timing advance information of the neighbor cells. However, the terrain was tough to determine the possible area with more than one base station. The calculated TA values are around 35, it means 19 km radius round area which is huge. First, the possible cells are closed one by one and the timing advance of each cell is noted. The use of that TA value, it gives different bowes as per cell. We detect a new TA value 2, which corresponds 1.1 km radius round area. Then, the bow areas are converged to have limited coverage areas. The mountaineers are found in that given possible bow areas.

5. CONCLUSION AND FUTURE WORK

With the use of handover relations, timing advance information and the coverage calculations, we reduced the possible search area of a mobile device. Firstly, the signaling information is checked to determine the serving cell information, and the coverage of the cells are investigated. Secondly, handover-signaling information is analyzed to determine how to use it. To narrow the searching area, the handover relations can be used to find the relation of different cells and define their intersection. The parallel process can also be done on the neighbor cells of the serving cell. Finally, if the inputs are suitable, we used the TA information to draw a bow to have more restricted area.

For a future work, the first aim is to reduce the running time for the whole process to 10-20 minutes. Mobile operators can keep the updated coverage information for each cell at a database. Keeping the cell information to reduce the calculation process time is considered as the first step. As the second step, the new simple program is developed to take only the handover relations and timing advance values. As a final, another algorithm is required to combine all that information. In the future the system first be generalize in Turkish mobile operators, then it may be adaptable to other global operators.

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